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## Article

# Perceptions of Urban Pollution of River Dependent Rural Communities and Their Impact: A Case Study in Bangladesh

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**Abstract:** This study considers the Old Brahmaputra River, Bangladesh, as a case study regarding community perceptions on urban pollution and its impact on rural communities. In doing so, in-depth individual interviews ( $n = 195$ ), key informant interviews ( $n = 7$ ), and focus group discussions ( $n = 7$ ) were conducted by emphasizing different perspectives on urban pollution and its effects on people related to losses of fisheries resources, agricultural production, human health, and livelihood transformation. The findings illustrate that poor urban solid waste management and direct sewage discharge degrade rivers daily. The most vulnerable rural communities are directly dependent upon the river, including fishermen, farmers, and boatmen. Specific measures such as an effluent treatment plant should be established near the river, and households and commercial drains should be cut off from the direct connection with the river. Alternative income-generating activities for the stakeholders are suggested to safeguard the river from urban pollution and the wellbeing of the stakeholders.

**Keywords:** urban pollution; Old Brahmaputra River; rural communities; sewage discharge; livelihood transformation

## 1. Introduction

Urban pollution refers to the presence or introduction of poisonous or harmful substances in cities and urban areas [1]. Contaminants might reach surface water from a specific, identifiable source or a relatively large, poorly outlined area. Point source pollution originates in a single site, such as a pipe, tank, ditch, narrow pool, or sewer. Since point sources are easy to locate, they are also easy to block [2]. Non-point source pollution originates from larger regions, such as agricultural fields, livestock enclosures, or the atmosphere. Non-point source pollution is far more challenging to control than point source pollution because it comes from a wide range of contaminants [3].

Although natural sources cause some urban pollution, most hazardous emissions are caused by human activity. Because of humans and human activities, anthropogenic point sources of pollution, such as industries, factories, and modes of transportation, are usually on the rise in cities [1]. Pollution impacts the quality of air, water, land, oceans, and even climate [4,5], affecting human health and the ecosystem. Cities contribute significantly to pollution problems [6], as there is a close relationship between population density and

pollution levels [7]. The United Nations Environment Programme (UNEP) published a report in 2017 that identified the major pollution concerns of air pollution, water pollution, chemicals, and waste. These types of pollution exist and are exacerbated in cities [8–10]. Chemicals that remain dissolved or suspended in water and generate environmental reactions that might result in water contamination are the principal sources of water pollution [8]. In addition, chemicals can affect human health, including cell mutagenesis and the growth of antibiotic-resistant bacteria [11].

Water (freshwater) pollution and marine and coastal pollution are all important types of urban pollution [1]. Water is a necessary component of life for drinking, cleaning, cooking, firefighting, and manufacturing [12]. Maintaining health, food production, environmental management, and employment creation depends on clean water. Rivers with clean and plentiful water are the basis of thriving societies. A river is of great importance for communication, irrigated water, fish, groundwater reservoirs, the preservation of ecological diversity, the balance of the environment and temperature, and the provision of the waters for birds and animals. Unfortunately, water is still the worst-managed resource in the world despite its importance. The current trend towards industrializing and urbanizing can contribute to poor water quality by the indiscriminate disposal of solid waste, industrial waste, and other toxic wastes, which are critical environmental issues that threaten human existence [13]. The present study focuses on the perceptions on urban pollution of river-dependent rural communities and their impact, using the Old Brahmaputra River in Bangladesh as a case study. The Old Brahmaputra River is the lifeline of the Mymensingh District. Recently, this river has been facing different problems, pollution from different sources such as municipal solid waste dumping near the riverbed, direct sewage connections, and commercial steamer waste infringing the rights of neighboring people to the river because they are river dependent rural communities and have a direct connection with the river. Besides, due to changes in stream direction, the river is gets less water during the dry season.

For this reason, the biodiversity of the river and its fish population are severely hampered. Many people directly or indirectly depend on the Old Brahmaputra River for their livelihood. About 75% of people who live beside the river are dependent on the Old Brahmaputra River for fishing [14]. However, various anthropogenic pollutants and morphological changes of the river affect the people's livelihood adjacent to river. As a result, the people dependent on the river, such as fishermen and boatmen, are forced to change their livelihood [15]. The declining trend of fish resources in the river and lack of working capital were identified as the major constraints for the fishermen of the Old Brahmaputra River [16]. Most fishermen face a wide range of vulnerabilities, including shocks, trends, and seasonality. This is because the ecosystem of the resource base on which their livelihood depends (i.e., the Old Brahmaputra River) has been degraded severely, resulting in a significant decline in fish catch due to a combination of factors, such as over-fishing, use of destructive fishing gear, water pollution, siltation, rapid urbanization, and environmental degradation [17].

The world's most significant health hazard is polluted water [18]. Three major societal processes—natural resource exploitation, industrialization, and urbanization—are largely responsible for the pollution. Urbanization and industrialization are the primary offenders for the despoliation of many lakes and rivers. With the rapid development of the economy and accelerating urbanization, there has been continuous pollution of rivers, causing damage to into rivers, seriously polluting the water system. As a result, the river's function as a resource has been lost, and the urban ecology and the aquatic environment have deteriorated enormously. The problems of urban river pollution and ecological damage are increasingly critical. According to statistics, there was almost no completely natural river globally at the beginning of the 20th century [19]. Up to 90% of wastewater in developing countries flows untreated into rivers, lakes, and highly productive coastal zones. Over 80% of wastewater worldwide is not collected or treated, and urban settlements are the primary source of pollution [20]. Few regions in the world have a comprehensive response to this

challenge, such as the European Union (EU), which has the European Commission (EC) Water Framework Directive [WFD], including the daughter directives on hazardous substances and groundwater, as well as the previous UN agreements HELCOM and OSPAR. In the last two decades, having this regulatory framework, the rivers' chemical and ecological quality in the EU has been substantially improved. For example, in the European Union, countries where less than 80% of the population are connected to public urban wastewater treatment systems include Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Ireland, Italy, Lithuania, Poland, Romania, Serbia, Slovakia, and Slovenia [21]. In EU-27 countries (EEA 2020), 69% of the population were connected to tertiary level treatment and 13% to secondary level treatment. As such, the EC WFD might serve as a best practice example for an implementation approach to improve river quality. In 2015, members of the United Nations agreed on 17 sustainable development goals to be achieved by 2030. According to Goal 6, "By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally" [22].

This focus on water quality suggests great concern for the global control of urban river pollution. The expansion of the sewerage system has not kept pace with urbanization in developing countries, which has serious consequences for the quality of water in urban rivers. By the 1970s, countries in Europe and the United States had stopped discharging wastewater directly into urban rivers by developing nearly complete sewer systems and wastewater treatment plants (WWTPs). As a result, water degradation slowed significantly in many urban rivers, while water quality gradually recovered [23]. About 40% of the food supply worldwide is cultivated using irrigation, and water is a significant part of various manufacturing procedures. Thus, water availability at the regional and seasonal levels, and surface and groundwater quality, controls the development of the environment and economic growth. Water quality is negatively affected by unregulated human activity and increased urbanization, increasing population, industrial manufacturing, climate change, and other variables. The resulting water contamination constitutes a significant threat to human and environmental health [24,25].

### *1.1. Level of Urbanization in Bangladesh*

Bangladesh is a densely populated country. In this country, 162.7 million [26] people live in 147,570 square kilometers, with a population density, around 1115.62 inhabitants live per square kilometer of the country [27]. The growth rate of the country's population is 1.37% [28], with the urban and rural populations being 23.3% and 76.7%, respectively. The country's urban population will be 38% in 2020, as estimated by the United Nations Population Division in 2016 [29]. Bangladesh is the world's seventh most populous country, with the highest population density. Since independence, Bangladesh's population grew until 1991; it began to decline over the last two decades. Thus, the annual exponential growth rate of the urban population is substantially more significant than the rate of population growth. Table 1 shows that the pace of urban population increase was highest from 1974 to 1981 (10.66%).

**Table 1.** Urbanization and Urban Population Growth Rate scenario in Bangladesh (1951–2011).

Census Year	Total National Population (Million)	Growth Rate of National Population (%)	Total Urban Population (Million)	Level of Urbanization (%)	Decadal Increase in Urban Population	Annual Exponential Growth Rate of Urban Population (%)
1951	44.17	0.50	1.82	4.33	18.38	1.69
1961	55.22	2.26	2.64	5.19	45.11	3.72
1974	76.37	2.48	6.27	8.87	137.57	6.66
1981	89.91	2.32	13.23	15.18	110.68	10.66
1991	111.45	2.17	20.87	19.63	57.79	4.56
2001	123.10	1.47	28.61	23.10	37.05	3.15
2011	150.40	1.37	42.11	28.40	47.19	4.12

Source: Government of Bangladesh: Bangladesh Population Census, 1991 [30]. BBS, 2003 1981; Report on Urban Areas, 1997; and Preliminary Report, Population [31]. Overview of Urbanization in Bangladesh-Nazrul Islam-2013 [32].

In 1974, the urban population was 6.27 million, had more than doubled by 1981, and is now 42.11 million, accounting for 28.4% of the country's population. Between 1974 and 2011, the number of people living in cities increased by seven times, totaling 35.84 million [33].

### 1.2. Human Development Index (HDI) Value and Rank Regarding Bangladesh

Bangladesh's HDI in 2019 was 0.632, ranking it at 133rd out of 189 countries and territories. Bangladesh's HDI increased 60.4% from 0.394 to 0.632 between 1990 and 2019. Table 2 summarizes Bangladesh's performance on each of the HDI indicators. Bangladesh's life expectancy at birth increased by 14.4 years between 1990 and 2019, while the average school time increased by 3.4 years, and the projected school time increased by 6 years.

Between 1990 and 2019, Bangladesh's GDP per capita increased by around 220.1% [34].

**Table 2.** Bangladesh's HDI trends are consistent with time series data and new goalposts.

Year	Life Expectancy at Birth	Expected Years of Schooling	Mean Years of Schooling	Gross National Income (GNI) Per Capita (2017 PPP\$)	Human Development Index (HDI) Value
1990	58.2	5.6	2.8	1554	0.394
1995	62.0	6.6	3.3	1752	0.434
2000	65.4	7.5	4.1	2002	0.478
2005	67.8	8.4	4.5	2383	0.514
2010	69.9	9.2	5.3	3117	0.557
2015	71.5	10.3	5.8	3936	0.595
2016	71.8	10.8	5.9	4143	0.606
2017	72.1	11.2	6.1	4340	0.616
2018	72.3	11.6	6.1	4643	0.625
2019	72.6	11.6	6.2	4976	0.632

Source: Human Development Report 2020, UNDP [34].

### 1.3. Waste Generation

Most solid waste is generated by rapid urbanization, industrialization, and better lifestyles. Bangladesh's per capita national income reached USD 1751 in 2017/2018 with a GDP growth of 7.86%, converting the country from a less developed country to a lower-middle-income country [35]. Significant economic development has resulted in significant lifestyle changes that have resulted in urbanization and a high standard of living. Previous studies [36–38] showed that Bangladesh's rapid urbanization and population growth are responsible for a large volume of waste products. The volume of waste in 1970 was 11,000,000 tons and increased to 52,000,000 tons in 2015 at a rate of 1,334,300 tons per year [38]. According to two separate studies, the total amount of municipal waste (MSW) generated in urban areas of Bangladesh by 36,986,768 city dwellers in 2013 was 520,919 tonnes/year (rate of 0.35 kg/head/day), while the total amount of urban waste

in 2015 was 511,000 tons/year of 39,488,000 inhabitants (0.32 kg/person/day) [38,39]. According to another estimate, municipal waste generated 14,778,497 tons of waste in 2012 out of a population of 155,727,053 tons. [40]. In several municipalities, household waste's average production is between 0.2 and 0.56 kg/person/day [41]. By 2025, the amount of waste in the metropolitan regions of Bangladesh is expected to increase by 0.6 kg/person/day [42], with a total amount of waste of 57,718 tonnes/day [43].

#### 1.4. Waste Generation Per Capita

The daily waste generation rate per person was estimated at 0.56 kg per capita per day in 2014 [43]. This rate has increased over the last 20 years. It is seen that it was 0.31 kg per capita per day in 1991 and 0.41 kg per capita per day by 2005 [44,45]. The daily waste generation rate is expected to reach 0.60 kg per capita per day by 2025, according to predictions made before the millennium shift [46]. The daily waste generation will reach 0.75 kg per capita per day by 2025, according to a more recent World Bank prediction [43].

Solid waste generation in urban areas: Bangladesh generates around 25,000 tons of solid waste every day, equating to 170 kg per capita per year. Dhaka generates one-quarter of the country's urban waste. Due to population growth and per capita waste generation rise, total urban solid waste is expected to reach 47,000 tons per day by 2025. In 1995, the average production of urban solid waste per person was 0.49 kg/person/day, but this figure is anticipated to rise to 0.60 kg/person/day by 2025. Data on waste collection efficiency in various urban regions ranges from 37 to 77%, with 55% [47].

Wastewater generation in urban and rural areas: Water contamination levels vary substantially between urban and rural areas (Table 3). Scarcity of water is a severe issue in urban areas, and surface water is primarily contaminated by illegal sewage discharge into bodies of water. Residents in rural areas have better access to water sources, and there is still a scarcity of wastewater treatment plants in these areas. Villagers often discharge raw sewage into surrounding bodies of water, even though this sewage has significant potential for reuse in agricultural areas [48]. Domestic wastewater is estimated at 4.874 billion tons per year, while industrial wastewater is 0.452–24 billion tons. [49].

**Table 3.** Volume of wastewater generation.

Region	Reporting Year	Wastewater Generated (Volume)
Bangladesh	2000	0.725 km <sup>3</sup> /year It is estimated that 38,573 billion tons of freshwater are extracted. Agriculture consumes approximately 44% of this water through irrigation and evaporation. The remaining 56% is discharged into the environment as wastewater, including 628 trillion tonnes as industrial wastewater and 314 trillion tonnes as municipal wastewater.
Global	2017	

Source: United Nations (UN), 2000 [50]; United Nation Wastewater Development Report (UNWDR), (UNESCO, 2017) [51].

Pollution of river bodies has become an essential issue because surface water quality measures and sanitation are inadequate or not. Wastes are usually discharged without treatment into the receiving water bodies. The discharge of raw sewage, garbage, and solid waste are threats to the diluting capabilities of rivers in major cities. The natural purification of polluted water is never rapid, while heavily polluted water can last for a long time (days) until a significant degree of purification is achieved [52].

## 2. Old Brahmaputra, Pollution, and Its Rural Community

Bangladesh is a riverine country. More than 700 rivers intersect and cross the country like a complex network. The Brahmaputra basin is one of the main basins that go through



it. Its old channel is known as the Old Brahmaputra River. The Brahmaputra is a mighty river in the Asian region whose old stream passes through the Mymensingh district. It is situated in the north-central zone of Bangladesh, which originates from Bahadurabad Ghat and goes through Jamalpur, Sherpur, Mymensingh, Kishoreganj, and Narsingdi. Its length is 283 km, and the average width is 200 m [53]. The old Brahmaputra was the main channel of Brahmaputra before 1762. However, after an earthquake with 7.5 magnitude, the channel of Brahmaputra at Bahadurabad Ghat point switched southwards and opened as Jamuna due to tectonic movement [54].

The Brahmaputra River is the world's fourth-largest river in the South Asia region in terms of annual discharge. Usually, the Brahmaputra discharges around 20,000 m<sup>3</sup>/s annually [55]. The river has a sediment load of around 735 million tons per year and a specific flood discharge of 0.149 m<sup>3</sup>/s/km<sup>2</sup> [56]. The Brahmaputra River drains an area of approximately 580,000 km<sup>2</sup> and is shared by four countries: 50.5% in China, 33.6% in India, 8.1% in Bangladesh, and 7.8% in Bhutan. The Brahmaputra River runs for 2880 km (1625 km in China, 918 km in India, and 337 km in Bangladesh) before draining into the Bay of Bengal via a shared canal. The Brahmaputra is divided into two branches in Bangladesh. The much bigger branch continues south as the Jamuna and flows into the Padma, while the older branch curves southeast as the old Brahmaputra and flows into the Upper Meghna. Both paths finally join near Chandpur in Bangladesh, where they flow out into the Bay of Bengal [57].

### 2.1. Land Cover

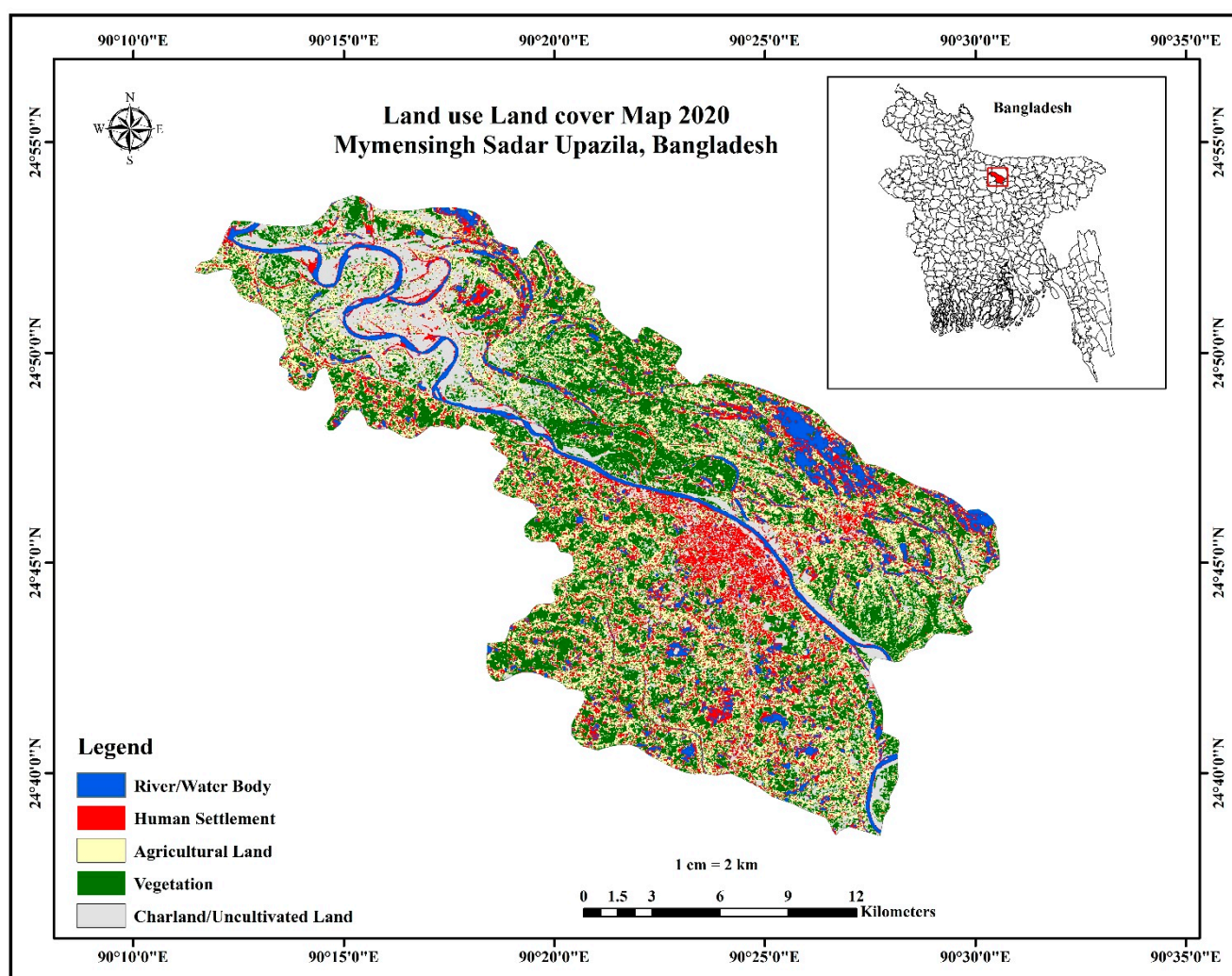
The Brahmaputra basin as a whole has about 14.5% forest cover, 44% grasslands, 14% agricultural lands, 12.8% cropland/natural vegetation mosaic, 2.5% barren/sparsely vegetated land, 1.8% snow and ice, 0.02% urban land, and 0.05% permanent wetlands [57].

According to the land cover map, the percent area of Mymensingh Sadar Upazila has the above scenario. River/Water Body is 8,270,696%, Human Settlement is 15,771,353%, Agricultural Land is 28,856,767%, Vegetation is 31,642,576% and Charland/Uncultivated Land is 15,458,607% (Figure 1).

### 2.2. Population

With around 83 million people living in all four countries, the Brahmaputra Basin is diverse in ethnic, socio-cultural, and linguistic groupings. For example, Bangladesh is home to around 41% of the basin's inhabitants [57].

A shifting process seems to have taken place over 30 years. Old Brahmaputra River is the lifeline of Mymensingh District. Recently, this river has been facing different problems, pollution from different sources such as municipal solid waste dumping near the riverbed, direct sewage connections, and commercial steamer waste infringing the right of neighboring people to the river because they are river dependent rural communities who have a direct connection with the river. Besides, due to changes in stream direction, the river receives less water during the dry season. For this reason, the biodiversity of the River and Fish population is severely hampered. Many people directly or indirectly depend on the Old Brahmaputra River for their livelihood.



**Figure 1.** Land Cover Map of Mymensingh Sadar Upazila 2020.

### 2.3. Pollution Status of Old Brahmaputra

The Brahmaputra is a transnational river that springs at Mount Kailash in the Himalayas and meanders through Tibet, China, India, and Bangladesh. From the Himalayas to the Bay of Bengal, the entire distance is 2900 km [58]. However, the health of this mighty river is now at stake due to pollution.

**Water quality:** In 2016, the pH level of Brahmaputra River water varied from 7.18 to 7.78, while the standard range for fisheries is 6.5 to 8.5. DO concentration varied from 5.8 to 7.6 mg/L, while the environmental quality standard (EQS) for DO for fisheries is 25 mg/L. BOD concentration varied from 1.0 to 2.2 mg/L while EQS for fisheries is  $\leq 6$  mg/L. TDS level ranged from 52.2 to 168 mg/L and was within the EQS (2100 mg/L). Suspended Solid (SS) varied from 10 to 45 mg/L. Chloride level was from 4.0 to 12.0 mg/L, which is less than EQS (600 mg/L) for treated wastewater from industrial units [59].

According to the existing Environment Conservation Rules 1997, water standards for different parameters have a specific range value (Table 4). However, when the values exceed the range, the water becomes unusable for drinking, bathing, irrigation, etc. This scenario is seen for the old Brahmaputra river's water as some of these values exceed the standards range. Unusable conditions are created due to excess sewage discharge, and other polluting factors are also related to this process. The Environment Conservation Rules permit a specific range of sewage parameters' volume for disposal to conserve water quality and keep it usable and pollution-free (Table 5) [60].



**Table 4.** Surface water standards for inland bodies of water.

Best Practice Based Classification	Parameter			
	pH	BOD mg/L	DO mg/L	Total Coliform Number/100
a. Source of drinking water for supply only after disinfecting	6.5–8.5	2 or less	6 or above	50 or less
b. Water usable for recreational activity	6.5–8.5	3 or less	5 or more	200 or less
c. Source of drinking water for supply after conventional treatment	6.5–8.5	6 or less	6 or more	5000 or less
d. Water usable by fisheries	6.5–8.5	6 or less	5 or more	—
e. Water usable by various process and cooling industries	6.5–8.5	10 or less	5 or more	5000 or less
f. Water usable for irrigation	6.5–8.5	10 or less	5 or more	1000 or less

Source: The Environment Conservation Rules, 1997; Ministry of Environment, Forest and Climate Change; Government of the People's Republic of Bangladesh [60].

**Table 5.** Permissible sewage discharge limit.

Parameter	Unit	Standard Limit
BOD	mg/L	40
Nitrate	mg/L	250
Phosphate	mg/L	35
Suspended Solids (SS)	mg/L	10
Temperature	Degree Centigrade	30

Source: The Environment Conservation Rules, 1997; Ministry of Environment, Forest and Climate Change; Government of the People's Republic of Bangladesh [60].

Electrical conductivity for irrigation water—2250  $\mu\text{S}/\text{cm}$  (at a temperature of 25 °C); sodium less than 26%; boron less than 0.2% [60].

According to the rule, this restriction applies to both surface and inland water discharge, and prior to final discharge sewage must be chlorinated [60].

**Metal pollution:** Metal pollution is now a significant issue for the entire world. Heavy metals are highly hazardous due to their abundance, persistence, and toxicity. Heavy metals are polluting river water daily. River water serves as a repository for heavy metals as wastes and effluents are discharged without consideration for the river's health. High concentrations of heavy metals such as Al, Mn, Ni, Pb, and Cu (Table 6) directly discharged into the Old Brahmaputra River contribute significantly to surface water and sediment contamination [61].

**Table 6.** Observed concentrations of heavy metals in the water of the Old Brahmaputra River.

Heavy Metals	Mean Concentrations (mg/L)
Pb	0.11
Cr	0.01
Cd	0.001
Cu	0.12
Hg	0.001
Al	6.87
Ni	0.44
Co	0.2
Zn	0.01
Mn	1.44

Source: Monitoring and assessment of heavy metal contamination in surface water and sediment of the Old Brahmaputra River, Bangladesh (<https://www.researchgate.net/publication/333942241>, accessed on 10 November 2021) [61].

The Old Brahmaputra is a very sacred river. It has great spiritual value. This river is involved in the life of people of different religions, different castes, and professions. Sanatana Hindus believe that they become pure and purified by bathing in this river every

day. They believe that sin is dissipated and eliminated by every bath in this holy water. However, the river water is now polluted and unsuitable for bathing. Moreover, bathing regularly causes a variety of skin diseases. As a result, it is harmful to one's health and impedes religious and spiritual practice.

Perception studies are helpful as they describe attitudes, social norms, and perceived behavior control as potential factors influencing people's intentions to perform a behavior [62]. In addition, understanding people's perceptions, attitudes, and emotions are essential in developing strategies [63]. The importance of the perceptions, experiences, and knowledge of local rural communities about pollution and wastewater has gained prominence in discussions of mitigation of wastewater pollution in developing countries, and among international development organizations [64]. Understanding stakeholders' perceptions toward poor urban solid waste management and direct sewage discharge to the rivers are important for planning for effective policy implementation [65]. Several studies have analyzed people's perception of water quality in the context of, for example, drinking water [66], lifestyle disruption and recreational activities [67], surface water sources in different water usage situations [68], and agricultural water usage [69]. This paper attempts to help bridge the knowledge gap by determining the perceptions, experiences, and knowledge of urban pollution of river-dependent rural communities and its impact on them, and the specific measures to mitigate the existing issues.

Considering the Old Brahmaputra River basin area in Bangladesh as a case study, the research questions of the present study are as follows:

- i. What is the perception of the rural riverine communities on pollution of the Old Brahmaputra River at present and earlier?
- ii. What are the perceptions of rural communities on the impacts of urban pollution on the river, and how to mitigate the negative impacts of urban pollution on the river?

### 3. Theoretical Framework

This study used problem tree analysis (also known as Situational analysis or Problem analysis) as an analytical framework. The term "problem tree" refers to a conceptual model used as a diagnostic tool to analyze a sequence of events that eventually leads to a problem [70]. It is a visual problem-analysis tool (Figure 2) that can be effectively used by both field development staff, and the community, to specify and investigate a problem's causes and effects and highlight their relationships. As the name implies, this tool resembles a tree. In the lower part of the drawing, the tree's roots metaphorically represent the causes of the main problem. The tree trunk at the center of the drawing represents the main problem and the tree branches, on the upper side of the drawing, provide a visual representation of the effects of the main problem [71]. A problem tree/solution tree analysis is a helpful tool for reviewing existing knowledge about the causes of an issue and how to solve it. A good problem analysis consists of several steps. At least five steps can be distinguished [72]: identifying major existing problems based upon available information, selecting one focal problem for the analysis, identifying direct causes and effects of the focal problem and constructing a problem tree showing these relationships, transforming the problem tree into the objective tree and obtaining root solutions to the focal problem from the objective tree.

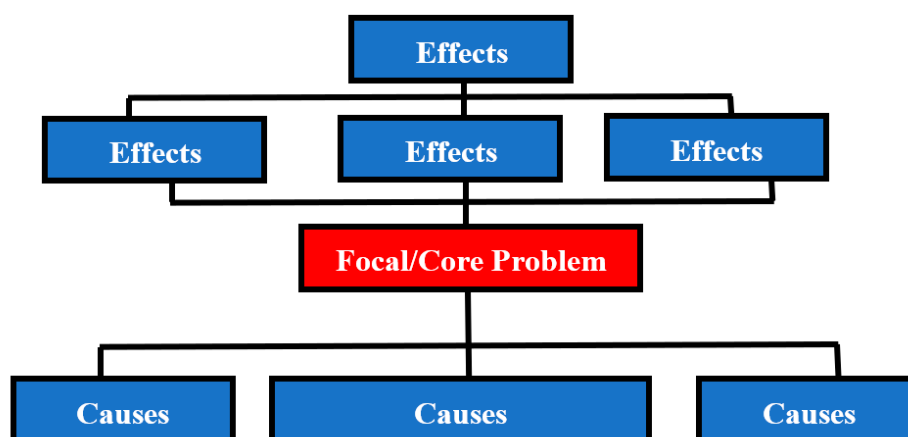


Figure 2. Problem tree [73].

#### 4. Materials and Methods

##### 4.1. The Study Area/Location

The study was conducted in the Old Brahmaputra River basin (Figure 3).

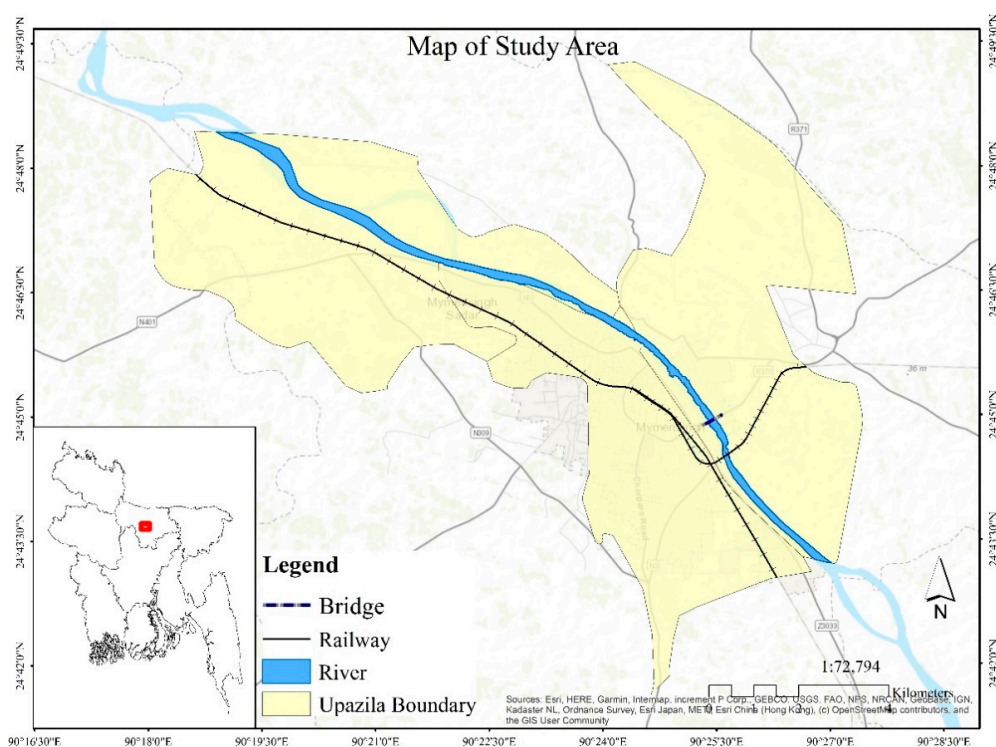


Figure 3. Study area.

Fieldwork was carried out in four villages near the Old Brahmaputra river's bank for this study: Char Ishwardia, Char Kalibari, Char Gobindapur, and Jailkhanar Char. Old Brahmaputra is a river de-branched from the main Brahmaputra on  $25^{\circ}15'36.9''$  N  $89^{\circ}43'18.2''$  E and goes towards southeast direction around 200 Km before meeting Meghna at Kishoreganj on  $24^{\circ}02'11.4''$  N  $90^{\circ}58'46.1''$  E. As the river is very long, studying the whole river basin is challenging. Therefore, we selected a specific area of the adjacent rural part of the Old Brahmaputra River. This part of the river has cultural, religious, and economic value, and the people of these areas are mainly river-dependent rural communities. On one bank of the river, the Mymensingh City is situated. On the other side, the administration has identified the total area as a rural and rural-urban area. More than 18 drains discharge the

urban wastewater to the river without any treatment by the city. Therefore, this significantly impacts the rural area as most people are deeply interrelated with the river. Our study area consists of four Mauza (Administrative Unit): Char Ishwardia, Char Kalibari, Char Gobindapur, Jailkhanar Char. The total area covers around 30 square kilometers. The total population of the study area is 36,996 [74].

#### 4.2. Method

To determine perceptions in regard to pollution and its influence on river-dependent individuals over the last ten years, this study conducted qualitative and quantitative research using primary and secondary data. In addition, we used various qualitative methods for empirical data, including in-depth interviews and focus group discussions (FGDs). Qualitative methods were used to answer questions about experience, meaning, and perspective—most often from the participant's standpoint. Information was collected from both males and females in the area. To find proper interviewees, a "snowballing" sampling method was chosen [75]. The more knowledgeable fishermen, farmers, business people, and boatmen were interviewed using a purposive sample strategy [76]. Altogether, 195 questionnaire surveys/interview Schedules were carried out. We followed statistical methods and the concept of saturation to estimate the total respondent number. The sample size for the interview was selected based on the required information and according to the principle of data saturation [77]. This was the study's fundamental guiding principle for determining sample sizes. For the total population (36,996), the confidence level was 95%, and the margin of error was 7%. Thus, we had 195 respondents. This figure was distributed mathematically for each Mauza (Administrative Unit) individually. According to Population-Household's ratio, we tried to select each respondent from the study area with five houses differences for each sample. In total, seven key informants (KII) were interviewed from the study area, which included the UP Chairman, the Assistant director of DoE (Regional), the Superintending Engineer of Bangladesh Water Development Board (Regional), the City corporation mayor, a teacher, a social worker, and a river activist.

In addition to the in-depth interviews, seven focused group discussions (FGDs) were conducted (Table 7) among male fishermen ( $n = 6$ ), housewives ( $n = 6$ ), female job holders ( $n = 6$ ), businessmen ( $n = 4$ ), male laborers ( $n = 6$ ), male farmers ( $n = 5$ ), and male boatmen ( $n = 5$ ).

The FGDs (Table 8) lasted on average 50–60 min. The statements or key points were digitally recorded with permission from all participants after completing the sign-in consent form by the participants. For this study section, semi structured interview questions were developed, allowing for open-ended conversation. When informants expressed a desire to remain anonymous, extensive notes were collected during the interview.

The communities participated in a pilot interview to test the questionnaire's applicability. After that, the questionnaire was appropriately adjusted before being administered. In addition, the questionnaires were adjusted for each interview based on the interviewee's role and representation.

We prepared similar questions for the focus groups, but we allowed new topics throughout the discussions. The use of focus groups assisted in keeping the findings open to debate and discussion, especially among persons with conflicting perspectives and interpretations on some of the most sensitive subjects.

They were asked several closed-ended and open-ended questions such as did they change their occupation in the last 20 years? If yes, why had they changed their occupation? What are the causes of pollution of the river water? What sort of diseases are they suffering now from this water pollution? Do they catch any fish in the river now or find enough fish? Do they regularly bathe in the river now, and what was the previous scenario?

**Table 7.** Sample distribution of the present study.

Sampling Method	Total Number	Distribution		
Interview Schedule	195	Male	154	
		Female	41	
Key Informants Interviewed (KII)	7	Local government representatives	Upazila Chairman City corporation Mayor	1 1
		Local governments administrative personnel's	Assistant director of DoE (Regional)	1
			Superintending Engineer of Bangladesh Water Development Board (Regional)	1
		Teacher	Headmistress	1
		River Activist	Local river protection activist	1
		Social Workers	General Secretary of Environmental Protection and Development Movement-EPDM	1
Case Studies	2	Male Farmer	1	
		Milkmaid	1	

**Table 8.** Stakeholders and number of participants in each FGD.

Stakeholders	Number of Participants
Male Fishermen	6
Housewives	6
Female Job Holder	6
Businessman	4
Male Laborers	6
Male Farmers	5
Male Boatmen	5

Finally, for suggesting recommendations, they were asked what sort of measures the government has taken to control this pollution? Or what role should the government and non-governmental bodies play?

Secondary data were collected about the perception of the degree of water pollution of the river and to understand the studied area's history, culture, livelihood, and economic condition by analyzing research done by various researchers. Several books, journals, newspapers, magazines, publications, websites, reviews, and articles were regarded as secondary data sources. In addition, many published documents on water were discussed from a literature review to determine the causes of water pollution and its impact.

After collecting data from interview schedules and focus group discussions, they were transcribed into English and evaluated using thematic analyses on related topics [78]. A descriptive strategy for flexible data reduction is specified as thematic analysis [79]. To support and explain the respondents' opinions and give them a voice, we often included actual statements from the interviewees. Initial data analyses with respondents were conducted to avoid personal biases in interpretation. In addition, such preliminary assessments were given in the focus groups to confirm the authenticity of the respondents' statements. Field notes taken during the data collection process aided data processing. The



data was compiled and analyzed using SPSS 25 and then presented in textual, tabular, and graphical formats to better understand rural communities' perspectives of urban pollution.

## 5. Results

Most rivers near Bangladesh's major cities have been contaminated for different reasons over 20 to 25 years; for example, the lifeline of Mymensingh District is the Old Brahmaputra River. Recently, the river has faced various problems, and pollution from various sources has been observed. This has seriously hampered the river-dependent life and biodiversity of the river.

### 5.1. Socio-Economic Condition of Rural Communities

According to data derived from the Bangladesh Bureau of Statistics (Small Area Atlas Bangladesh; Mymensingh), our study area mostly belongs to a rural area with some rural-urban phenomena. Among the respondents, 21% are female, and 79% are male. Most of the respondents are from the age range 30 to 60 years (Table 9). The majority of respondents were over the age of 30 years. As a result, their perspectives should represent a reasonable amount of experience and maturity. Their educational status is not high; the majority are illiterate or have little education. Most of them earn from 200 to more than 300 takas per day and 34% of the respondents have to do a part-time job to earn more.

#### 5.1.1. Perception of Pollution and Pollution Level at Present

Of the respondents, 91.79% think that the river is now polluted, 26.7% think the river pollution level is severe, and 39.5% think it is extremely severe. They are not comfortable with the odor, with 68.2% experiencing a foul and irritating odor, especially in the pre-monsoon period. In the pre-monsoon period, watercolor becomes blackish, and the taste of the river water is not tolerable. Therefore, watercolor has changed drastically in recent years.

#### 5.1.2. Main Causes of Pollution: Urban Pollution

Most (91.79%) respondents think the river is polluted due to direct drain connections (63.6%). In their opinion dumping wastes at the river site and wastewater from the city drains are the main causes of river pollution. Two waste dumping spots and 18 drains are present (two are pipe type and operated by household and hotel, and the remaining sixteen are structured drains established by Mymensingh City Corporation) and directly connected to the river (Figure 4). City corporation workers dump wastes near the Bangladesh China friendship bridge. These places are temporary dumping sites for the dry season situated on the riverbed (Figure 4). When river water increases during the monsoon, it washes away the whole area and the water becomes more polluted. Most (92.8%) of respondents observed a large amount of waste floating on the river, and 91.8% said they saw it during the monsoon. Structured drains constructed by the city corporation and drain connections from homes or hotels contaminate the river significantly. There are also many inactive drains directly connected to the river. Most of the houses have a passive sewerage connection with the river.

This study and another previous study [80] found both organic and inorganic hazardous substances from the temporary dumping site (Table 10). Hazardous substances found from dumping sites are both organic and inorganic. A 50 m buffer zone for these dumping sites is shown in Figure 4. Organic wastes mainly included rotting food, paper and paper board, plastics, clothing, and wood, whereas inorganic wastes included metals, glass, dirt, ash, and hospital waste.

**Table 9.** Respondents' socio-economic status.

Socio-Economic Characteristics	Percentage (%)
Age (years)	
20–30	17.44%
30–40	29.74%
40–50	23.59%
50–60	21.54%
60–70	7.69%
Educational Status	
Illiterate	41.03%
Primary level or below	34.87%
Secondary level or below	19.49%
Higher Secondary level or upper	4.62%
Housing condition	
Tin shade with bamboo	20%
Tin shade with tin	65%
Straw component	12%
Brick building	3%
Occupation	
Farmer	23.08%
Housewife	11.28%
Student	2.05%
Laborer	20%
Boatman	8.21%
Fisherman	3.59%
Businessman	25.64%
Others (service holders)	6.15%
Daily income in Bangladeshi taka (BDT)	
No income	13.85%
<100	3.08%
100–200	5.13%
200–300	18.97%
>300	38.46%
Not answered or unable to calculate	20.51%
Part-time Job Status	
Agriculture/Day Labour/Boat making/Sand mining	34.4%
None	65.6%

### 5.1.3. Time Period of River Pollution Started

Most people do not use river water now (49.74%), but they used it ten years ago (77.9%). Then they could drink the river water directly. Laborers used to drink river water during their work, but they stopped drinking it due to its foul odor. They noticed the pollution starting from 5 to 15 years ago (75.3%) and choose alternative sources for safe water (39.49%). Ten years ago, the Brahmaputra was not as polluted as today. Homemakers used river water for most of their household work, even cooking. Nowadays, this has decreased. A few (1.03%) people do not use river water for specific minor issues, whereas 22.56% do not use it due to pollution, and 39.49% have alternative sources.

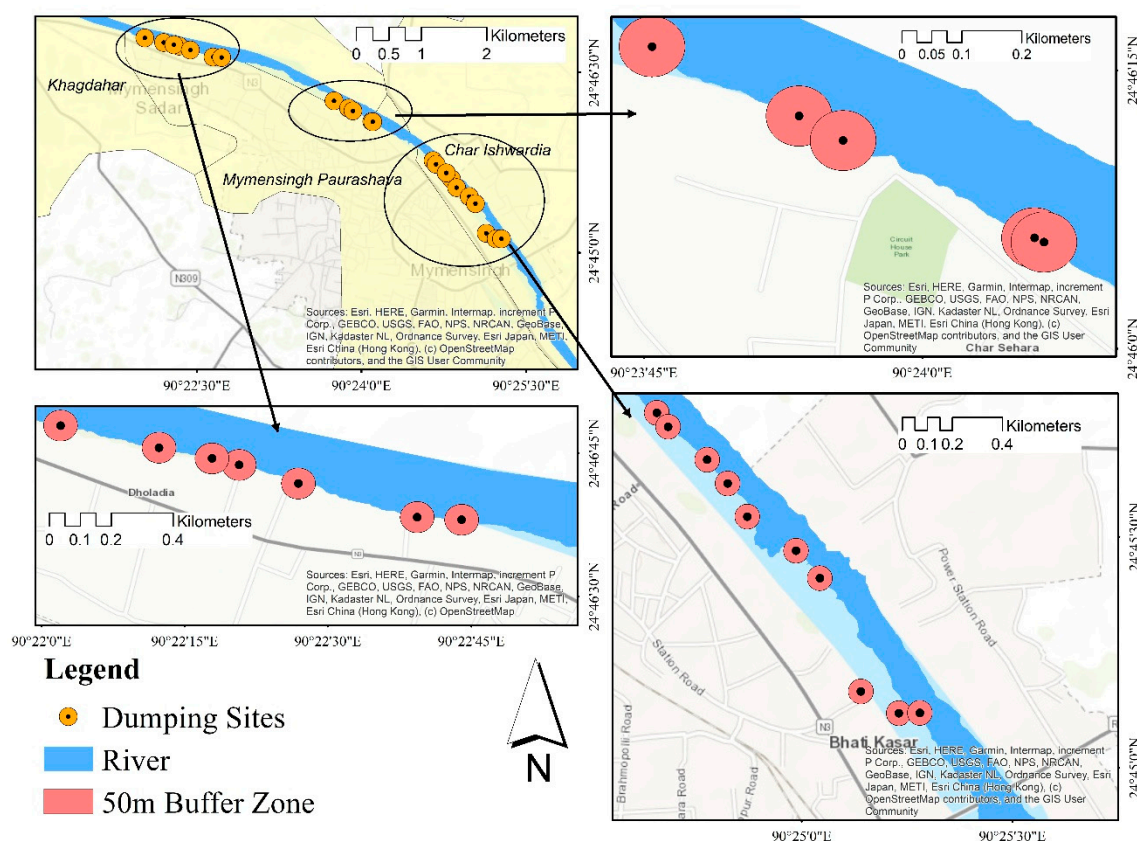


Figure 4. Structured Drains and Visible Waste Dumping Sites and their 50 m Buffer Zone.

## 5.2. Impacts on River Dependent Rural Communities

### 5.2.1. Dependency and Usages of River Water by the Riverine Community

A majority (77.9%) of people used the river water ten years ago, while the remaining 22.1% did not. Then they used river water for drinking, bathing, household works, agricultural activities such as irrigation, and animal bathing. The river water was fresh and clean then. There was no foul odor or taste, so it was not polluted then. That is why the riverine community frequently used it for drinking and daily work. Nevertheless, 50.26% of people still use river water for either bathing or some household work but do not drink river water directly because of severe pollution and direct drainage connections with the river. So, river water usage has reduced 27.64% within the last ten years due to pollution and availability of alternative sources like tube wells (22.56% of people do not use river water due to pollution, and 39.49% of people have created alternative sources because of polluted water). Many people face a scarcity of potable drinking water due to pollution, and dependency on the river decreases day by day.

### 5.2.2. Detrimental Effect on the Health of Rural Riverine Communities

Almost half (48.2%) of adjacent river people suffer from different waterborne diseases. Homemakers and children are great sufferers. They use river water for bathing, washing clothes, cleaning plates and glasses, and suffer from different waterborne diseases such as itching. Their children mainly suffer from different skin diseases due to polluted water as they regularly bathe in the river. We found that many people living near the bank of the Old Brahmaputra are suffering from waterborne diseases, and their dependency on the river for daily activities is decreasing day by day (Figure 5).

So, they must choose alternative sources for freshwater.

**Table 10.** Some potential hazardous substances found at the temporary dumping site.

General Composition	Typical Composition	Detailed Composition	Reference
Organic	Food putrescible	Food Vegetables Waste meat Waste fish Dead plants	Wood
	Paper	Paper and paperboard/Cardboard	
	Plastics	High-density polyethylene Low-density polyethylene Polystyrene Other multilayer plastics	
	Clothing	Rubber Lather Textiles (wool, cotton, etc.) Carpets	
	Wood	Wood	
Inorganic	Metals	Tin cans Aluminum Ferrous metals Spoons	This Study
	Glass	Colorless Colored	
	Dirt, ash, etc.	Dirt screenings Ashes Stones Broken bricks	
	Hospital Waste	Operation theater waste Sharp needles, blades, syringes, scalpels Glass Waste	

### 5.2.3. Decrease of Fisheries Resources or Fish Biodiversity and Impacts on Fishermen

Due to pollution and less water availability in the Old Brahmaputra, fisheries resources are declining day by day (Figure 5). Most (99%) of the people claimed that fish biodiversity had decreased drastically. Over half (59.7%) of the respondents think that fisheries resources declined due to decreased water flow from upstream. Some (15.38%) think river pollution causes fish declination. Some (14.36%) mentioned decreased river depth. A few (9.74%) blamed overfishing for fish declination. Boal (Freshwater Shark), Ayer/Guzi (Giant River-catfish), Gulsha Tengra (Day's Mystus), Pabda (Butter Catfish, Baim (Tire track ell) were available in the river decades ago, but now fingerlings of Punti (Pool barbs) or Chingri (Prawn) are rarely found in the net.

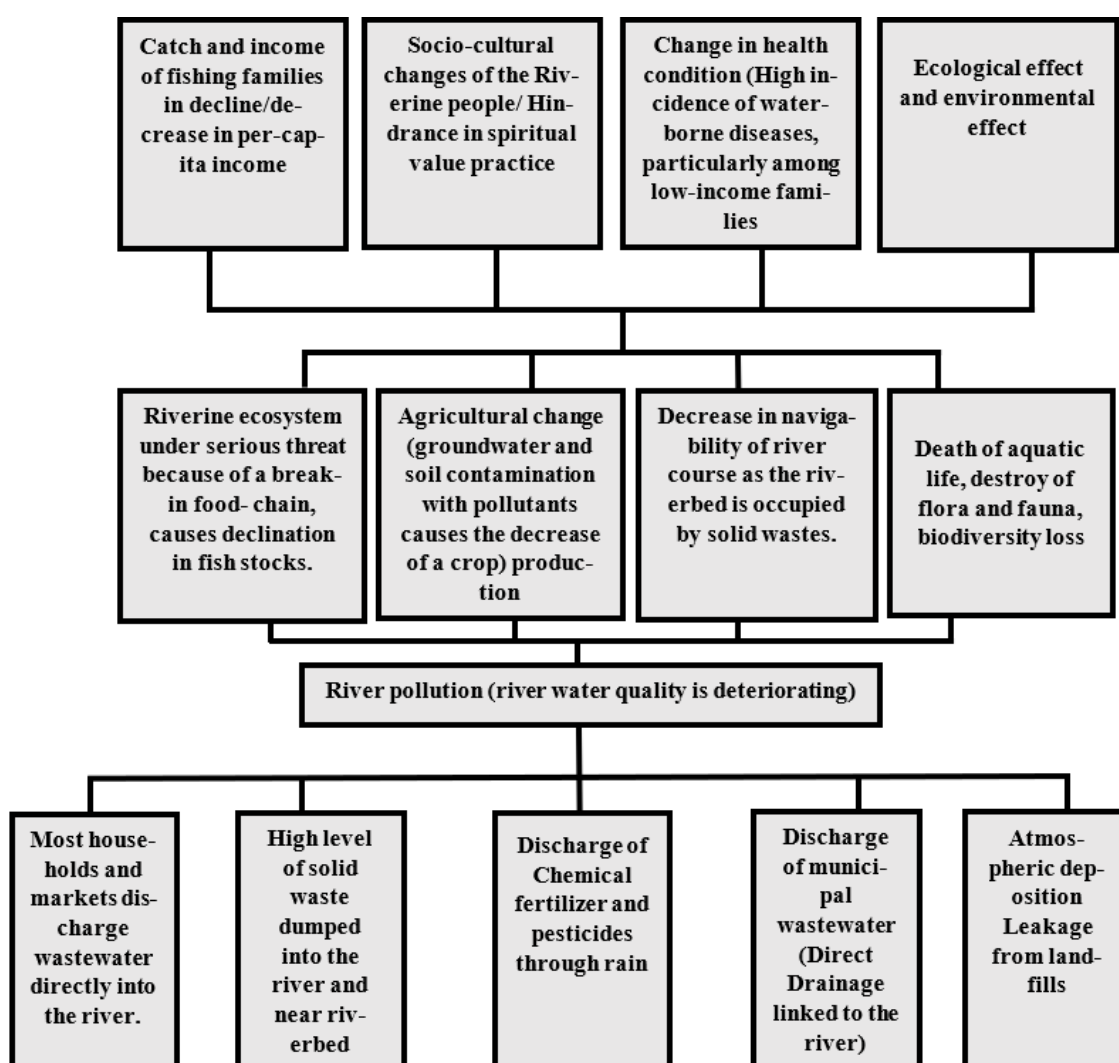


Figure 5. Analytical framework (Problem tree) of the social impact of water pollution.

#### 5.2.4. Livelihood Transformation of Rural People

One of the significant consequences of river pollution is livelihood transformation of rural riverine communities that are directly dependent on the river (Figure 5). Some of the major groups are described below.

**Women from Different Professions:** In this group, most women work in jute mills, some work in hospitals and others in the private sectors. However, most of them have worked in the agricultural sector in the past. Because of river pollution, they changed their job fields. Before that, they worked in agricultural fields with their husbands. Due to the contamination of the river, agricultural production has decreased drastically since the river water was used directly for irrigation most of the time. They used river water because of its proximity to the river, and there was a lack of deep wells in the region. That is why women have gradually switched to other professions with their husbands to feed their families properly.

**Farmers:** The river water is polluted, so farmers are not using river water for irrigation nowadays. In their opinion, crops are being damaged when river water is used for irrigation. Due to pollution, inadequate water in the river, and riverbank erosion, most farmers have changed their professions.

**Businessmen:** They face navigation problems in transporting their goods and materials through the river because wastes occupy the river. Pollution results in less navigability. As a result, many river-dependent businesses have been stopped, and many people have transformed their livelihood from river transport-based businesses.



**Boatmen:** Tourists feel uncomfortable on boat journeys on the Old Brahmaputra due to water scarcity in the river and the foul odor during the dry season. In the past, recreational activities such as boat racing took place in the river. However, these activities do not take place due to less water. So, it also has an impact on their livelihood. Many boatmen have changed their profession due to the navigation problem in the river. The river has aesthetic value, but the foul odor due to pollution has reduced this value and that is why the number of tourists has decreased.

**Fishermen:** Due to pollution and less water availability, fisheries resources are declining day by day. Fishermen can only catch fish during three months of the monsoon, and for the rest of the season they have to depend on other work for their livelihood. Several fish species were available decades ago. Fishermen are forced to leave their profession due to the decline of fish. Besides, most of them have to change their profession during the dry season and get work as day laborers. Most (71%) of fisherman respondents have part-time jobs because fisheries resources have declined, and it is hard to raise a family or earn a livelihood by fishing. In their opinion, pollution and scarcity of water are also responsible for the decline of fisheries resources. Water becomes putrid during Falgun-Chaitra (Mid-February–Mid April). Many fish species have become extinct in the Old Brahmaputra River basin due to various factors, including pollution, habitat destruction, river water scarcity, decreasing depth, and early catches of indigenous species, notably smaller fish.

The story of Abdus Salam (45 years old) reflects this situation more explicitly.

Chor Ishwardiya is a union located on the banks of the Old Brahmaputra River. Md. Abdus Salam is a resident of this union whose age is approximately 45 years. Although he is currently engaged in farming, he is a fisherman. From a very early age, he used to catch fish in the Brahmaputra and earn his living by fishing. From an early age, he loved fishing. The old Brahmaputra was then a vast fish reservoir. Boal, Ayer, Gulsha, Tengra, Pabda, Baim were available in the river. He used to catch fish and sell them at the market. At that time, he could support his family doing this. Due to the gradual decline in the amount of water and the number of fish in the river, and since he did not have his boat and net, it was becoming difficult for him to run the family with the rest of the money after paying dues to the merchant. About 20 years ago, he bought a net with many loans to support his family properly. However, he could not repay that debt till now. The amount of water and fish in the river has dropped drastically due to siltation and pollution over the past few years. He could catch fish during three months of the monsoon, but during the rest of the season had to depend on other works for his livelihood. For these reasons, he has not fished for the past two years. He has changed his profession, due to the above circumstances, and because he does not own his house, he has changed his home at various times.

For this reason, he has moved far away from the river. However, he wishes to return to his old fishing profession if the fish stocks return because he loves fishing.

**Laborers:** They think river pollution or bank erosion do not affect their livelihood directly. Nevertheless, they are also affected in some cases as they live near the river. They used to drink river water during their work but stopped due to its foul odor or pollution. A few decades ago, the river was full of fish, and they used to catch fish for recreational purposes. However, nowadays, this interaction has decreased drastically.

### 5.2.5. Hindrance of Spiritual Value Practice

Beenpara village is located on the banks of the Old Brahmaputra River. Anjali Rani Bin (40) is a resident of this village. Her original residence was in India. However, her family came to Bangladesh long before the country's partition, settling on the bank of the Old Brahmaputra. Currently, she is living here with her family members. She is a milkwoman or milkmaid by profession. She earns her livelihood by selling milk. In addition to selling milk in nearby houses around the village, she also sells milk in the city areas, and occasionally sells vegetables in the city's markets.

To people such as Anjali Rani Bin, the Old Brahmaputra River is regarded as the goddess Ganga. To them, the river Brahmaputra is very sacred. The old Brahmaputra has a

sacred religious feeling to them. They consider this river's water as pure as their mother's milk. By bathing in this river, they become pure and are purified every day. They think that omnipotence is dissipated and eliminated in this holy water. That is why they have never agreed to call the river polluted or contaminated. They think it is a sin to call the river polluted. The Ganges (river water) can never be profane or polluted. To them, this river is godlike, and the source of their livelihood has evolved based on the river since ancient times. They never dump garbage in the river. All the garbage is buried in the ground on one side of the courtyard of their house because they do not want to profane the holy river by dumping garbage. To them, the river is always holy and pure. This sacredness of the Old Brahmaputra is fundamental to them. The river is inextricably linked with the life of Anjali Rani Bin and the lives of her family. So, they always try to preserve this sanctity.

### *5.3. Willingness and Efforts to Keep the River Good*

In the focus group discussion, all the stakeholders mentioned the importance of improving water quality. They were keen to participate in the activities to improve the water quality of the Old Brahmaputra. They narrated the story of the excellent water of this river, with which their golden past was connected, as well as the contrasted picture of today's squandered water. According to them, their economic and social condition was good when the river was good, and they were well-off. As the river water quality began to decline, their condition gradually worsened. They always tried their best not to pollute the river in any way by their work. Because the river's health is linked to their wellbeing, rural riverine people are willing to participate actively in any action made by the government or higher authorities to keep and improve the river's health. They wish to improve water quality and are eager to help with any activity that would restore the river and its water. In every FGD, all stakeholders raised this same voice and showed their active keenness for the restoration and future betterment of the river. They want different government organizations and concerned authorities to take initiatives to restore the river. The government and non-government organizations have taken very few steps so far. They think it is crucial to take more effective actions to revive the river by involving rural inhabitants.

### *5.4. Demand to the Government and Concerned Higher Authorities*

Respondents urged effective waste management, action against illegal sand mining, and a better water transportation and navigation strategy. They stated that the most significant cause of river contamination is unplanned unborn waste handling. They demand effective garbage management, dredging, and embankment construction on the river's rural side.

One of the study area's respondents voiced the following demand to the government: "During the holy baths, we smell a bad odor every day. This stench sometimes disturbs our minds and hampers our emphatic feeling of a holy bath in the majestic Brahmaputra. We make every effort to avoid polluting the river in any way. To prevent pollution, we bury all of our household wastes in the ground adjacent to our houses instead of throwing them into the river directly. We want urban people and municipalities to manage urban waste properly effectively. While we constantly protect the river near us, the mismanagement of urban waste renders our great river lifeless and hurts religious sentiment. Unfortunately, the government has not yet taken any action in this regard. We want the government to take decisive action in this regard soon."

An aggrieved middle-aged fisherman from the study area raised this demand to higher authorities as follows.

"We want river pollution to end because, as a result of the loss of river water quality, the number of fish in the river has reduced significantly. Furthermore, while we go to the river for fishing, our bodies experience much itching. Due to pollution and depletion of river water, we can no longer find any fish. However, the river water was not so bad before. There is no fish in the river today due to the lack of strict measures by the

government, such as there is no proper place for the dumping of solid wastes, discharge of the urban liquid waste directly in the river without any treatment. We want the government to take appropriate action in this regard. We want proper municipal waste disposal, measures against illegal sand mining, proper navigation, and fishing facilities through regular dredging operations.”

## 6. Discussion

### 6.1. Urban Pollution

According to the study findings, untreated urban wastewater from drains directly connected to the river is the primary cause of river pollution. Furthermore, temporary garbage dumping stations on the river’s bank harms water quality. The main pollution problem is connected with excessive nutrient loads entering the Old Brahmaputra River, primarily from untreated municipal sewage, household waste, and street drainage [81]. According to the municipality’s conservation inspector and sanitary inspector, around 100 tonnes of garbage are dumped daily near the riverbed beside the bridge [82]. However, the fact is that it is not a usual dumping spot for the municipality. River pollution is particularly severe and crucial in metropolitan stretches in southern Asian nations such as Nepal, India, and Bangladesh due to massive amounts of pollutant load released by urban activity. Two significant causes are primarily responsible for water pollution in Bangladesh, India, and Nepal. The first is the unrestricted discharge of untreated or partially treated wastewater (from both home and industrial sources), as well as pollution-laden urban runoff [83]. This is due to a lack of suitable urban sanitary infrastructures, such as sewage, adequate on-site sanitation, wastewater treatment facilities, and effective solid waste management. The second issue is a lack of adequate regulatory pollution control measures and their stringent implementation in practice. Massive discharges of municipal wastewater (sewage and industrial wastewater) and urban drainage into rivers have resulted in high organic and pathogenic levels in all urban surface waterways [84].

Despite various pollution sources that significantly contaminate the river, the current study tried to identify the severity and effects of urban pollution on the river ecology using focus groups and in-depth interviews. This paper suggests some potential solutions for resolving the issue and ensuring the proper management of municipal wastewater. Municipal waste and industrial effluents, both of which contain trace metals and pathogens, pollute water resources. Cu, Zn, Mn, Fe, Ni, Cd, Cr, Co, Pb, and other trace metals are generally present in low concentrations in water. However, increased concentrations of these metals have been discovered due to anthropogenic activities. Some research findings have shown that some trace metals have carcinogenic or harmful effects on humans and the environment [85].

The respondents, including government and non-government officials, call for some urgent measures from the Mymensingh City Corporation (MCC), Department of Fisheries, Bangladesh (DoF), Department of Environment (DoE) and the Bangladesh Inland Water Transport Authority (BIWTA). Participants urged proper management and treatment of urban solid waste and municipal wastewaters, and not to directly mix these with river water. They also urged for purification of municipal sewage water before discharge in the river and removal of garbage dumping sites near the riverbed. The earlier investigation also discovered that the water in the Old Brahmaputra River is unfit for human consumption. River water is now used for sewage discharge, boating, fishing, and religious rituals. Impurities from fertilizer and pesticide application and municipal and household waste discharged into river water through sewerage systems significantly impact river water quality. Based on the river pollution index, cluster analysis, principal component analysis, and factors analysis, Bhuyan et al., 2018 found that the Old Brahmaputra River water is less highly polluted. Due to haphazard industrialization, urbanization, and agricultural activities, the river water is getting more polluted day by day. The water of the Old Brahmaputra River proved to be not entirely safe for aquatic organisms, irrigation, and other purposes [86].

The Brahmaputra River was once suitable for aquaculture and irrigation, but its quality has rapidly deteriorated by expanding industry and untreated municipal waste. As a result, the Brahmaputra River is in poor condition, and heavy metal concentrations in river water are gradually rising, contaminating aquatic organisms such as fish [87]. Previous research has focused solely on the detrimental consequences of municipal wastewater on river water. However, the nature and number of urban pollution sources have not been thoroughly documented, and no link has been established between several sources of urban pollution and river contamination. Point sources of pollution are mainly municipal wastes (drainage linked to the river; Field Observation, 6 June 2018), industrial wastes, open defecation, and religious ritual activities [88].

On the other hand, non-point sources are agricultural activities, runoff from agriculture, fields, streets, roads, manure discharge, commercial steamer wastes, and flood. According to the present arrangement of the officials of the Mymensingh municipality, daily waste dumping has a tremendous negative impact on the ecology of the already dying ancient Brahmaputra River. Fisheries' resources have decreased due to pollution, resulting in significant changes in the water current, depth of water, and temperature. A survey with the fishermen shows that about 60 to 65 species were found in the Old Brahmaputra River five years ago. Now the number has declined at 39 species [14]. Thus, the river's water quality is suitable for fisheries biodiversity [89].

## 6.2. Impacts on Rural Riverine Community

Urban pollution is a problem that affects the life and livelihoods of the rural community on a large scale. Many people suffer from scarcity of pure drinking water, are affected by different waterborne diseases, and dependency on the river decreases daily. They have to choose alternative sources for freshwater. Communities that are directly dependent on the river are great sufferers. Fishermen, farmers, boatmen, and business people are forced to change their profession, and the rest have to do other jobs most of the time around the year. River-dependent people, especially fishermen, have to change their profession drastically because of fish population decline in the river. Farmers are facing challenging times due to less production of crops, and boatmen are losing their work due to less water or less navigability in the river.

Due to urban pollution, river water quality is deteriorating day by day. Rapid net runoff from urbanized surfaces and sewage water outflows not linked to a wastewater treatment plant (WWTP) have appeared a serious hazards to the ecological values of water bodies and the availability of good quality water necessary for fundamental socio-economic processes. [90–92].

As a result, the river ecosystem is under serious threat because of a break-in the food chain causing declining fish stocks, death of aquatic life, and destruction of aquatic flora and fauna. Groundwater and soil contamination with pollutants causes decreases in crops, resulting in significant agricultural changes in the study area. Solid waste, organic matter, metals, acidifying compounds, and nutrients leach into the river due to land-use practices and point source loading within the drainage basin [93]. These compounds can potentially alter the river's aquatic environment and oxygen balance affecting the makeup of aquatic organisms such as plankton, benthic species, plants, and animals [94]. The water of the Old Brahmaputra River is not suitable for aquatic organisms, irrigation, and other purposes [86].

Unsanitary conditions and water pollution make the situation so dire that waterborne diseases are now widespread in Bangladesh [95]. About 41,000 children under the age of five die each year from diarrhea. The number of diarrheal illnesses and deaths in 2009 was double that of the previous year [18]. In addition to diarrhea, other diseases such as cholera and typhoid are associated with water and cause disasters detrimental to human health [46]. Non-biodegradable excessive solid wastes cause a decrease in navigability of river course because of a decrease in river depth. All these changes in the ecosystem due to urban pollution result in socio-cultural changes of the riverine people [96]. The catch and income of fishing families are declining and decreasing per-capita income of

various professions; changes in health conditions result in the exceptionally high incidence of waterborne diseases, particularly among low-income families. Pollution creates groundwater contamination and causes skin rashes and other health issues such as cancer, reproductive diseases, typhoid fever, and stomach disease. Ecosystems are destroyed by the rising temperature in the water, and aquatic animals are killed from suffocation. Solid waste accumulation and soil erosion in rivers sometimes lead to flooding. Fishermen and boatmen have moved to other occupations. This triggers specific changes in per capita income, health status, agricultural changes, socio-cultural change, and changes in the financial condition of fishermen, farmers, and boatmen. Thus, the water pollution of this river has a significant adverse effect on society.

### 6.3. *Loss of Spiritual and Aesthetic Value*

The old Brahmaputra has lost its aesthetic values due to pollution as people are not comfortable with the foul odor from the river. It is a mighty river and is thought as sacred. This river has a religious significance to its rural communities and has a unique spiritual significance in Hinduism. Hindus consider this river's water as pure as their mother's milk. They believe that they become pure and purified by bathing in this river every day. However, the river water is now polluted and unsuitable for bathing. Bathing regularly causes a variety of skin diseases. As a result, the river loses its spiritual and aesthetic value day by day. According to the rituals, Hindus participate in a sacred bath in this river every year. Many people now feel uncomfortable bathing in the river due to pollution; evidence that pollution has prevented people from performing their religious rites. Since the river is sacred, they do not pollute it with their household trash and bury everything in their backyard or perimeter. However, they suffer the consequences of contamination by municipal waste.

### 6.4. *Limitations of the Research*

Recently Mymensingh has been declared as a new division of the country and a new city corporation. In order to develop the academic infrastructure of the new division, the government is conducting land acquisition activities at the northern side of the Old Brahmaputra river's Charland. People of the Charland are scared of these land acquisition activities. So, when we provided a questionnaire survey, they thought there might be other reasons instead of research. They thought we were government people and came because of the land acquisition issue. That is why some of the villagers within the study area did not cooperate with us. Conducting high-quality research work requires sufficient time and availability of respondents for the study. Due to participant unavailability and shortage of time, it was not possible to conduct more interviews with the study area. We also lacked questionnaire surveyors and data collectors for covering a vast study area. The government officials, UP members, chairman, and elites of the area were very busy during the interview and could not give sufficient time for KII.

## 7. **Conclusions**

The river is vital to the rural inhabitants of riverine Bangladesh, and their life and livelihood are reliant on it. The river impacts their religious beliefs, practices, and recreational activities as well. Pollution-free rivers and safe water help to meet their fundamental needs. The river has had a profound presence in significant activities of rural people. However, river pollution reduces their reliance on the river and undermines their fundamental rights. The old Brahmaputra is being polluted by inappropriate urban waste management. A considerable amount of wastewater is discharged into the river every day without any treatment. Waste dumping sites are situated on the bank of the riverbed, which is washed out during the monsoon every year. Polluted water results in aquatic flora and fauna decline, especially fisheries resource decline, causes skin diseases such as itching, waterborne diseases such as diarrhea, and livelihood transformation. The polluted river disrupts human-river interrelations, and people are losing their interest and dependency.



Rural people are now forced to lean towards alternative sources. There are scanty studies regarding the impact of urban pollution on riverine residents in the Old Brahmaputra River, including livelihood transformation and especially on fisherfolk. However, this study covers most professions and socio-economic changes due to urban pollution.

River-dependent people are the main stakeholders of a river, although the whole district and its people, and even some neighboring districts, are stakeholders. Adjacent rural people depend on the river, but it also has other cultural, religious, and aesthetic values. Therefore, it is necessary to involve all the stakeholders in protecting the river from pollution. If the Government and NGOs, and civil society organizations do not take proper steps shortly, the problem may create a more complex situation. Based on the stakeholder's perception we concluded that to recover from urban pollution and save the surrounding rural community, the following measures should be implemented:

- i. An effluent treatment plant should be established near the river so that discharged wastewater from the household, institutions, industries, and jail should be treated before it goes to the river. The Department of Environment (DoE) Mymensingh should take care of this. And enforce different river or environment-related laws. If people do not obey the rules, then legal action will be taken by DoE against them and also against the polluters. City corporations and CSOs will help DoE in this regard and enforce laws.
- ii. Households and commercial Drains should be cut off from direct connection with the river. Mymensingh City Corporation (MCC) should take the necessary steps. Structural drains of Mymensingh City Corporation should be deployed elsewhere and have no direct connection to the river. All the solid waste dumping sites should be transferred from the river area and maintained through a proper waste management system by the Mymensingh City Corporation (MCC). Illegal sand mining should be monitored, and the local administration should take legal action. Various NGOs will have to come forward and work together with the City Corporation to help.
- iii. River-dependent people, especially fishermen, should be helped by the Department of Fisheries (DoF), Bangladesh, during dry seasons until the river recovers from pollution and fisheries habitat restored. The DoF should arrange training. Further training sessions and seminars have to be organized for fishermen by the fisheries officers of DoF to provide all the knowledge about fish and fishing properly. The government should provide sufficient relief for them during the dry season when there is not enough water and fish available in the river.
- iv. Capital Dredging through regular maintenance is necessary for better navigation. Therefore, Bangladesh Inland Water Transport Authority (BIWTA) should take all the required measures.

We have attempted to lay some basic foundations for the perceptions of the urban pollution of river-dependent rural communities and their impact by pinpointing key issues underpinning different perspectives on urban pollution and its effects on people related to losses of fisheries resources, agricultural production, human health, and livelihood transformation. Alternative income-generating activities for the stakeholders were suggested to safeguard the river from urban pollution and the wellbeing of the stakeholders.

The government must take these key stakeholders into consideration when designing alternative income-generating schemes. However, further empirical research is necessary regarding integrating alternative income-generating schemes.

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